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## THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

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THE JOURNAL
OF
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OF CANADA

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# OBSERVATIONS OF VENUS IN 1943

By FRANCIS P. MORGAN

HEREWITH is a report, with drawings, of a series of observations of Venus which I have made during the past summer.

Observations were made at the Ville Marie Observatory with our 6-inch refracting telescope, using a 220-power eyepiece for the earlier observations; then the powers 150 and 110 as the planet came closer.

All observations were made by the writer except those from July 27 to August 5, which were by Mr. De Lisle Garneau while I was on vacation.

## REPORT

*May 29*—Well defined bright border around limb, slightly brighter near south cusp. Irregular terminator but little detail on disk.

*June 5*—Limb margin bright with bright area in northern hemisphere at approximately + 60°. No marked brightening at cusps. Dark area at terminator just south of equator.

*June 13*—No detail except for very small north polar cap and slight darkening at terminator.

*June 16*—No detail except for very small north polar cap. Terminator very straight.

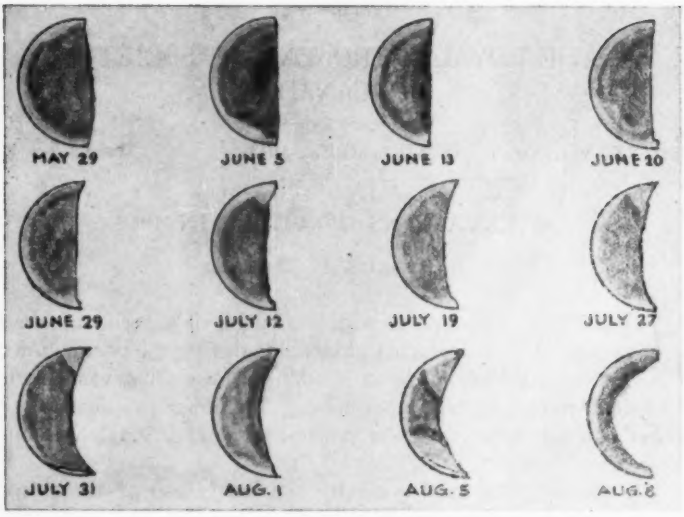
*June 20*—No change except that north polar cap protrudes slightly over terminator.

*June 24*—No change since June 20.

*June 29*—Limb margin brighter in northern hemisphere. North cusp cap protrudes a little further over terminator. Southern end of limb margin also protruding slightly.

*July 5*—North cusp cap smaller and less distinct. Limb margin uniform in brightness. No detail on disk since June 13.

*July 8*—North cusp cap smaller. Large south cap appearing. May have been present in previous observations but unnoticed since it is little brighter than limb.




DRAWINGS OF VENUS, 1943
as seen in an inverting 6-in. refracting telescope.
July 27 to August 5 inclusive by DeLisle Garneau; the rest by Francis P. Morgan.

*July 12*—North cap small but bright. South cap large but faint. Limb margin brighter toward south. No detail on disk.

*July 16*—Brightest part of limb around tropical zone. South cusp cap, if present, not distinguishable from limb margin. No change in north cap.

*July 19*—Slightly shaded areas on limb separating cusp caps from rest of limb margin. Pole caps equal in size but north cap the brighter. Centre of limb brighter than either cusp.

*July 22*—No change since July 19, but good atmospheric conditions and little agitation made possible to observe dark border inside limb margin. Probably present at all observations, but difficult to detect.

*July 27*—South cusp cap larger but less conspicuous than north cap.

*July 31*—South cap becoming more conspicuous.

*Aug. 1*—South cap not visible. North cap unchanged.

*Aug. 5*—Centre of disk shaded from limb to terminator. First disk shadings observed since June 13.

*Aug. 8*—Centre of limb margin brighter than either cusps. Slightdarkening around centre of terminator.

4235 Decarie Blvd.,
N.D.G., Montreal, Que.

## NIGHT FALL: LUXOR

By R. R. Thompson

I

Night fell on old Luxor:
Then o'er the desert, darkness swiftly crept,
And filled the distant valleys, where there slept
The spirits of a hundred Theban kings,
Whilst, save the rustle of the night-wind's wings
Through those vast temple halls and colonnades,
As if the ancient gods held court with shades,
No sound broke o'er the scene.

II

All nature, hushed in awe
Before the splendour of the dying day,
Lay silent, and below swept on its way
The Nile. E'en as I watched, the light had flown
The zenith's boundless spaces: then were sown
With countless stars the sapphire depths of night,
Whilst oceans of transparent amber light
Flowed down the western sky.

III

Above the Libyan hills
Some clouds hung flaming 'midst a blood-red glow;
Then fell on all the silent plain below
A silence more intense. Infinite space!
Infinite worlds of light! I hid my face,
And bowed my head, o'erwhelmed with such a flood
Of thoughts, too vast for finite minds: I could
But wonder, what is man?

IV

I leaned my arm against
A column of stupendous size, beside
Whose bulk a mote I seemed. In all their pride
The massive ruins seemed to say to me,
"Ye pass; but we, in our immensity,
"Live on eternal as the hills which gave
"Us birth, and as the Nile whose waters lave
"Out base, immutable."

V

It seemed that men were naught
But tiny insects, crawling, till they died

And crumbled into dust. Just then I spied
A star supremely bright, and swiftly sped
My thoughts o'er countless million miles of dread,
World-peopled Space to ask, if, there, are men
With minds like ours, who build great temples; then
Stand wondering at themselves.

VI

By thought I flew through Space,
And trod the outer spheres. I saw that man
Could n'er be measured by the cubit's span,
Nor weighed like stone; for he is god-like, vast,
Whose will-power raised these temples of the past,
Who understands the movements of the throng
Of Heaven, and measures Space; this flame of strong,
Undying energy.

VII

I looked around again
At those stupendous ruins of Luxor,
And spake my answer back: "Ye were no more
"Than shapeless stone till man created ye
"In his imagining, and painfully
"Subjected nature's powers to his will
"Till ye from out o' the bowels of your hill
"Were carved, and made yourselves."

VIII

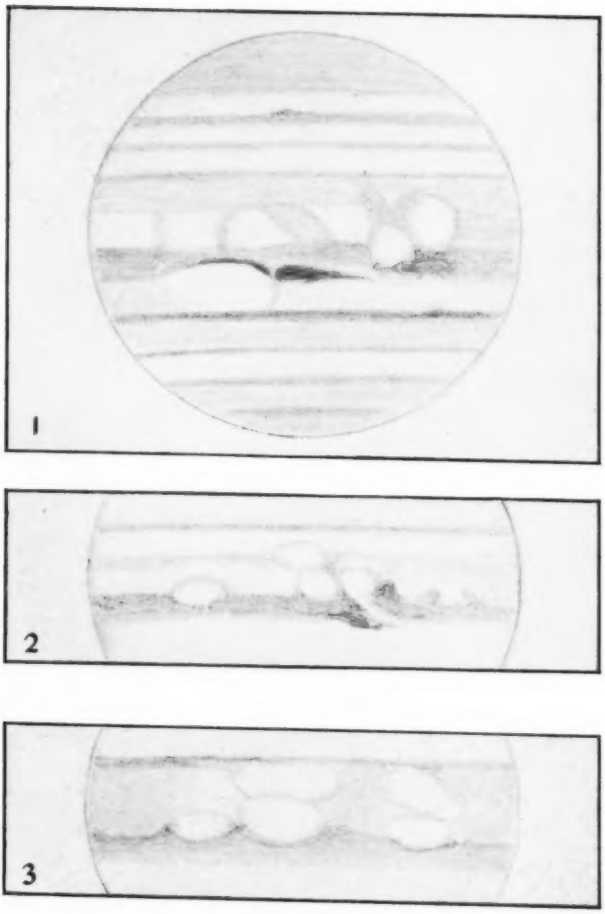
"We pass, but ye stay here
"Unmoving, senseless, dead, in slow decay.
"Ye truly spake: we pass, but on our way
"To solemn portals, some call Death, where all
"That chains us to this Earth aside shall fall,
"And we shall stand, and know as we are known,
"Be free to wander, where our thoughts had flown,
"Creation's furthest realms."

IX

"E'en now, with flesh-veiled sight,
"We thrill responsive to our Father's Mind
"Who wrought the sunset's glow, and we shall find
"Undreamed-of glories, when we grow as He
"Would have us grow, in endless harmony—"
Thoughts came too fast for words; but I had said
Enough, and, through the darkness with my head
Erect, passed on my way.

McGill University,
Montreal.

PLATE XI




DRAWINGS OF JUPITER, 1940-41 APPARITION

DATA ON DRAWINGS OF JUPITER

Fig. 1. Drawing of Jupiter, 1940 August 29, 9h 25m to 9h 40m, C.M. $281°_{1}$, $30°_{2}$, by H. M. Johnson using 8-in. reflector, 213X.

Fig. 2. Drawing of Equatorial Zone of Jupiter, 1940 November 15, 2h 56m to 3h 05m, C.M. $128°_{1}$, $4°_{2}$, by H. M. Johnson using 8-in. reflector, 213X.

Fig. 3. Drawing of Equatorial Zone of Jupiter, 1940 November 25, 1h 53m to 2h 03m, C.M. $228°_{1}$, $29°_{2}$, by H. M. Johnson using 8-in. reflector, 213X.

# THE 1940-41 APPARITION OF JUPITER

By W. H. Haas and H. M. Johnson

(With Plate XI)

## *Introduction*

THE 1940-41 apparition of Jupiter found the planet at $\delta + 14°$ at opposition on November 3, 1940 (U.T. will be used herein as the basis of dates and times) and hence well placed for study by northern observers. This paper will report the results of observations carried on by a small group of amateurs in the United States. Our group was active from June 14, 1940, to April 15, 1941; but naturally the planet was not seen to good advantage near the beginning and end of this period. The coöperating observers were as follows:

| Name | Station | Telescope | Remarks |
|---|---|---|---|
| D. P. Barcroft | Madera, Calif. | 6-in. refl. | |
| T. R. Cave, Jr. | Long Beach, Calif. | 6-in. refl. | |
| C. Cyrus | Lynchburg, Va. | 10-in. refl. | |
| W. H. Haas | New Waterford, Ohio | 6-in. refl. | |
| " | Columbus, Ohio | 12-in. refr. | O. S. U. Observatory |
| H. M. Johnson | Des Moines, Iowa | 8-in. refl. | |
| " | " " | 7-in. refl. | Unsilvered primary; aluminized secondary |
| " | Clive, Iowa | 12-in. refl. | Seldom used |
| F. R. Vaughn, Jr. | Des Moines, Iowa | 8-in. refl. | |
| L. J. Wilson | Nashville, Tenn. | 12-in. refl. | Chiefly photographic work. |

Information on methods of observing Jupiter and the nomenclature which we gave in an earlier paper[1] will not be repeated here.

## *General Appearance*

Figs. 1, 2, and 3 are perhaps typical pictures of the planet in 1940. The N.E.B., much the most readily seen and thickest of the

belts, contained many delicate rifts and dark condensations. Along either edge of this belt were dark humps, often the bases of projecting wisps, and bright areas, which frequently were rather diffusely bounded. The E.Z. detail was thus of the same sort as in 1939 but was less conspicuous. The N. Temp. B., the S. Temp B., and the S.E.B. N were also regularly seen; but all other belts were difficult for most of the observers. Johnson usually found the delicate E.B. to lie in the middle of the E.Z. However, he noted in excellent seeing on August 20 with C.M. $317_1°$ that following the C.M. this belt diverged from its normal position and lay close to the S.E.B. N, as it had in 1939.[1] The polar shadings were perhaps darker in June than in August.

Johnson observed that the S. Trop. Z. and the N. Temp. Z. were brighter than the rather dull E.Z., the N. Trop. Z., and the space between the components of the S.E.B. Haas also noted that the S. Trop. Z. looked brighter than the E.Z. or the N. Trop. Z. but thought this condition due only to a lack of dark markings in the zone named first. In late June Haas saw the N. Trop. Z. to be narrower than the N.E.B.; in July he found the former somewhat the wider; in September it was about twice as wide as the belt; moreover, on November 15 Johnson remarked on the great width of this zone. It appears clear that the zone gradually widened relative to the belt. The zone between the S. Temp. B. and the S.P.R., probably a combined S. Temp. Z.-S.S. Temp. Z., was seen by Johnson to be wider and brighter in mid-August than in June or July; and on September 7 Haas independently remarked on its width. It did not long remain notable, for Johnson saw it to be very dull on October 13 and narrow on March 12. This observer twice remarked that near $\lambda_2$ 140° the N.N. Temp. Z. was darkened and the N.N. Temp. B. and the N.N.N. Temp. B. thus joined by dark material. He further three times saw a N.N.N. Temp. Z. clearly.

Early in the apparition both Johnson and Haas sometimes found Jupiter rather quiescent and lacking in detail. This aspect may partly have resulted from a temporary loss of keenness of their eyes for Jovian features while the planet was near conjunction, but this explanation may not be sufficient.

### *Relative Conspicuousness of Belts*

We discussed in an earlier paper[1] some of the intrinsic difficulties in studying the darknesses of the belts. In 1940-41 we observed only their relative *conspicuousnesses*, i.e., integrated effects of darkness per unit area and width. Johnson ranked the belts according to their conspicuousness 95 times; Haas, 85 times. For observations after September 24 and for all observations of belts less marked than the S.E.B. N we are largely dependent upon Johnson only. The data for each belt were analyzed by semi-numerical methods which were necessarily varied somewhat according to the frequency with which that belt was seen. In addition to such other changes as will be described later, each belt was apparently subject to rapid and irregular changes in darkness that followed no law at all evident. Although it is true that observational errors would produce the same effect and that we have not yet been able to devise and apply suitable mathematical tests of the reality of such changes, we consider it most improbable that all fluctuations of this sort represent nothing but errors. Some typical and well-evidenced examples of such changes will be mentioned below.

The N.E.B. had regained its 1936-8 dominance and was almost always by far the most conspicuous belt. Haas obtained evidence of some variations in its darkness.

Unit area for unit area, the N. Temp. B. was at least at times much the darkest of the belts; but its narrowness caused it almost always to rank second or third, depending upon how it compared with the S. Temp. B. That these variations were due at least in part to real differences in the N. Temp. B. is shown by the fact that both observers sometimes saw definite differences in darkness in the section of this belt visible upon the disc at a given time. The N. Temp. B. showed no marked lightening or darkening during the course of the apparition but was very probably darker relative to the S. Temp. B. from mid-September to mid-December than at other times. In late June and July the former belt was fainter from $\lambda_2$ 160° to 280° than elsewhere, and some other similar temporary conditions are indicated. Of the irregular changes alluded to above these examples appear especially interesting: Near $\lambda_2$ 20° Johnson on January 12 and 31 found the N. Temp. B. inferior to

the S. Temp. B.; on February 10 he reversed the order near this longitude, an aspect confirmed by Haas on February 20; on March 5 Haas made the N. Temp. B. here equal to the N.E.B., and on March 30 he observed it to be inferior to the N.E.B. but far above the S. Temp. B. Near $\lambda_2$ 195°, Johnson on June 19 and Haas on June 29 made the N. Temp. B. superior to the S. Temp. B., but Haas on July 11 and August 2 and Johnson on six dates extending from July 20 to August 30 reversed this order in this portion of the planet. On August 5 Johnson thought this portion of the N. Temp. B. only equal to the S.E.B. N, which it had surpassed two days earlier.

Perhaps lighter than in the autumn of 1939,[1] the S. Temp. B. almost always came second or third, depending upon how it compared with the N. Temp. B. It is thus clear that the behaviour of the S. Temp. B. has really been discussed already. On July 20, Johnson noted that this belt grew much heavier and darker following the Red Spot Hollow (near $\lambda_2$ 190°). On January 3 and on March 9 he thought this belt especially strong near $\lambda_2$ 140°, a condition that must have developed after late September.

The S.E.B. N was seldom other than fourth (never lower) and was plainly fainter than in 1939.[1] It may have varied somewhat in 1940-41 but exhibited no trend toward either increasing or decreasing darkness throughout the course of the apparition.

The N.N. Temp. B. was usually fifth or sixth but sometimes ranked lower. Once again no trend is found. During at least part, and perhaps all, of the apparition the belt was lighter from $\lambda_2$ 0° to 40° and from $\lambda_2$ 160° to 240° than elsewhere. We mention some rapid changes observed in this belt by Johnson near $\lambda_2$ 60°: On October 5 it tied for fifth with the N.N.N. Temp. B.; on October 13 that belt surpassed it; on November 13 and 18 the N.N. Temp. B. equalled the N.N.N. Temp. B. and surpassed the S.E.B. s but by December 10 had fallen to equality with the S.E.B. s.

The S.E.B. s varied in rank from fifth to eighth. It exhibited a progressive fading during the apparition, presumably a continuation of the lightening begun in the autumn of 1939.[1] The belt was darkest near $\lambda_2$ 180° and thus near the Red Spot; perhaps a residual of the 1939 distribution of darkness over different longitudes[1] lingered. This belt also was subject to short-period changes. Near $\lambda_2$ 340° it was fifth on July 14 and August 7; by August 31 it was

here inferior to the N.N. Temp. B., and on September 8 the S.S. Temp. B. also exceeded it; on December 9 and on March 8 it ranked in this region the same as on August 31 except that it was equalled by the E.B. on December 9 and by the N.N.N. Temp. B. on March 8 (all observations by Johnson).

A belt at the north edge of the S.P.R. and considered to be the S.S.S. Temp. B. ranked from fifth to ninth when seen. It was at times either completely absent or *exceedingly* delicate, for Johnson on three occasions recorded nine belts without perceiving this one. The belt was distinctly more conspicuous before the middle of October than after. A short section near $\lambda_2$ 100° was the darkest part of the belt during most, and perhaps all, of the apparition. Near $\lambda_2$ 15° the S.S.S. Temp. B. ranked sixth and below the N.N.N. Temp. B. on August 29; on October 27, November 29, and January 12 it was there invisible, being hence inferior to the N.N.N. Temp. B., the N.N. Temp. B., the S.E.B. s, and the S.S. Temp. B; on January 31 it was the same as on August 29; and on February 10 it tied the N.N.N. Temp. B. for fifth.

The N.N.N. Temp. B., which usually lay at the south edge of the N.P.R., ranked from fifth to eighth when seen. Three times it was not perceived when eight other belts were recorded. This belt darkened steadily throughout the apparition. The section from $\lambda_2$ 200° to 280° was darker than most, or perhaps all, of the rest of the belt.

The S.S. Temp. B., a belt only slightly south of the S. Temp. B. and *perhaps* really a south component of that belt, ranked from fifth to ninth when observed, as happened only 28 times. There were about 25 occasions when Johnson saw eight or more belts but not this one. The S.S. Temp. B. was first clearly recognized on August 20 and probably was growing darker at that time. It was certainly much darker from mid-October to mid-December than from mid-August to mid-October but probably lightened again during the first few months of 1941. This belt cannot have been equally intense over all longitudes; for it was several times seen to be broken, to be composed of isolated faint splotches, or to resume after being absent in some longitudes.

The E.B. was far lighter than in 1939[1]; it had grown delicate, ranking from seventh to tenth. On the average it was distinctly

inferior to the nine belts described above. Johnson alone saw it, and he only 15 times; his results would make this belt perhaps strongest near opposition. With C.M. between $336_1°$ and $89_1°$ it was never seen at all certainly. On February 11 Johnson remarked: "I am fairly sure that the E.B. is much more evident than on February 8 when nearly the same region was viewed." On August 4 near $\lambda_1$ 250° he only "suspected" the E.B., but nine days later in the same longitude and with similar conditions of observation this belt was "evident." A large section of the belt centred near $\lambda_1$ 140° was found gradually to lighten from July to February.

Johnson several times saw distinctly "a dark belt or streak in the middle of the N.P.R."

*Colours*

Colour observations on Jupiter during the 1940-41 apparition consist of 267 estimates by Johnson between June 15 and April 15, 337 estimates by Vaughn between October 20 and February 6, and 385 estimates by Haas between July 7 and September 24. In order to secure more nearly uniform results on colours, each observer to a large extent employed one telescope at a fixed magnification and worked only in a clear and dark sky. Haas employed Eastman Kodak Co. Wratten Filters 25 (red), 47 (blue), and 58 (green) as an aid in distinguishing colours. It was found quite impossible to combine directly the work of the different observers; the differences among their impressions of the colour of a given region that will be mentioned later are largely or entirely merely differences in seeing and/or describing the same colour. Slight changes in colour are not easily disentangled from intrinsic errors in the observations, which cannot be readily subjected to a mathematical treatment; we shall indicate below what sort of changes is indicated as highly probable by a careful analysis.

Though probably more purple than in 1939,[1] the N.P.R. was nearly gray. Haas observed a mere tinge of purple with increasing frequency from early July to late September, and Vaughn remarked slight blues that grew less common from late October to early February. A maximum of blueness (or purpleness) in October appears not improbable. Vaughn occasionally recorded reds, yellows, and greens also.

Johnson found the N. Temp. Z. to be white or yellowish.

The N. Temp. B. impressed Johnson as dark red with a varying admixture of brown, Vaughn as usually bluish but also at times as purplish, violet, and lavender, and Haas as a copper red of variable strength sometimes containing some gray (the red here being to him perhaps duller than in 1939[1]). Johnson's work shows that the hue was subject to no marked progressive variations from mid-June to the end of March and does not confirm Haas' result that the red was more conspicuous in September than in July or August. We give two examples of short-period and apparently entirely irregular changes that were found here (as in other regions): Near $\lambda_2$ 30° Vaughn saw "quite a strong purple" on November 18 but almost a neutral gray seven days later. Near $\lambda_2$ 130° Haas observed copper red on July 18, copperish on July 30, light copperish gray on August 4, light copper gray on August 6, copper red on August 18, rich copper red on September 4, 6, and 11, dark copper red on September 19, and rich copper red on September 21.

The three observers agree that the N. Trop. Z. was predominantly a rather dull white or yellow. Vaughn remarked other colours, which were faint and subject to rapid changes, and found the zone whiter in January and February than from October to December.

The N.E.B. impressed Johnson as a variable admixture of red and brown, the latter colour usually predominating, Vaughn as chiefly reddish brown, and Haas as copper red or blood red, both hues varying in intensity and in the degree to which they saturated the belt. Johnson found the colour fairly constant from June to March except for a minimum of redness near August first and a probable slight maximum of redness near October first; Vaughn observed the red to be more marked from late October to early December than from late December to early February; Haas perceived this colour to grow stronger from early July to late September. These three results are fairly harmonious. The N.E.B. moves in both systems of longitude.[1] It hence appears not improbable that if Jovian colours have a physico-chemical explanation, then the hues of the N.E.B. might exhibit a periodic variation in 47 days, the time in which System I rotates once relative to System II. The observations afford no evidence of such a cycle. Vaughn remarked a surprisingly strong violet hue in this belt on December 4

and a most unusual deep lavender colour on January 6; an unfortunate lack of observations closely adjacent in date and in region of the planet examined prevents much from being learned about the course of development of either colour. The hue of this belt at times almost certainly changed noticeably in only a few days; *e.g.*, near $\lambda_2$ 200° Johnson noted brownish red on August 2, brown with hardly a trace of red on August 4, and simply brown on August 6.

All three observers found the E.Z. primarily a rather dull white. Vaughn occasionally selected brighter colours. The hue of this region was fairly stable.

The S.E.B. N looked less red than in 1939[1] but perhaps only because it was lighter. Vaughn described it in October-February as almost always bluish; Johnson, in July-September as a changing combination of red and brown; Haas, during the same period, as light gray with a greatly varying copperish tone. One cannot safely conclude that the colour changed from red to blue as the apparition advanced, although Vaughn's work does indicate increasing blueness from late October to early January. Near $\lambda_1$ 160° Haas saw light copperish gray on September 19 but copper red the next night—good evidence of a very rapid distinct change in colour. Near $\lambda_1$ 25° Vaughn observed definite reddishness on October 20, gray with a bluish tinge on October 25, and bluish on November 2.

Johnson described the space between the components of the S.E.B. as dull yellowish on July 10; conceivably he saw a faded remnant of the bright yellow present there a year before.[1]

The S. Trop. Z. appeared white to Johnson and Haas; Vaughn recorded white but also other colours. The observer named last found the zone to be at least in part unusually dull in early February.

The S. Temp. B. looked brown to Johnson, with a changing but usually slight amount of red with the brown; brown, red, gray, and even occasionally other colours to Vaughn; and copper red to Haas, the hue being often dull and sometimes containing some gray. Johnson's work makes the belt grow steadily redder from early July to about November first and then become less so again, being nevertheless redder at the end of the apparition than at the beginning. Haas' results compatibly indicate an increase in redness in early September. Vaughn not too discordantly found the belt redder from mid-November to early December than either before or after.

Vaughn and Haas observed the usual rapid irregular changes in colour here, but Johnson found the hue to be fairly stable.

The S. Temp. Z. looked dull yellow to Johnson.

The S.P.R. was almost a neutral gray; Johnson saw some violet, Vaughn remarked several spectral tints, and Haas often observed a very slight purplish or violet hue. Observing from early July to late September, Haas found this shading most purplish from mid-August to mid-September. Observing from late October to early February, Vaughn remarked reds most often in October and pinks most often in November with increasing grayness from early December on. Here also rapid and irregular changes in colour are indicated. Near $\lambda_2$ 10°, Vaughn saw a definite red cast on November 2, only a faint pinkish tint on November 29, and an unusually dark yellowish on December 2.

Though making no regular estimates of colour, Barcroft frequently perceived brown and coppery tones in the darker belts and an aluminum-coloured cast to the S.P.R.

It will be noted that the various regions were coloured much as at the preceding apparition.[1]

### *The Probable Error of a Transit*

Knowledge of the probable error $r$ of a visually observed Jovian transit can greatly facilitate our study of drifts. One way in which this quantity can be determined is by a statistical study of transits relating to a well-observed and long-lasting mark. The Red Spot during the 1940-41 apparition met these criteria. Johnson, Barcroft, Vaughn, and Haas observed the centre and each end of this mark and obtained a total of 164 transits of these three points. Johnson suggested that longitudes derived from his transits prior to August 15 should be increased by 3°; a comparison of his longitudes with those simultaneously obtained by Haas both before and after the date in question confirmed this value, and the correction was hence applied. Each of the points observed was treated separately. Each transit was plotted by date $X$ and derived longitude $Y$, $X$ being measured in days and $Y$ in degrees. (Longitudes were computed to the nearest whole degree only). A Least Squares Line $Y' = a + bX$ was passed among the points; we thus in effect assumed that the period of rotation was constant during the whole

apparition. The residuals $Y' - Y$ of the points from the line were then examined. Transits having residuals too great to be reasonably attributed to chance were rejected, eight of the 164 being thus discarded. When the residuals of a particular observer were positive or negative by an amount significantly large compared to their internal precision, a correction was applied to longitudes found by that observer; but the only correction of this sort which was actually made was to subtract 6° from all of Barcroft's longitudes for the following end. The Least Squares Line was then redetermined; and finally the probable error $r$ of a single transit was given by:

$$r = 0.8453 \frac{\Sigma|Y' - Y|}{\sqrt{n(n-1)}},$$

$n$ being the number of observations. The results obtained were as follows:

| Red Spot | Least Squares Line | $r$ |
|---|---|---|
| preceding end | $Y' = 158°.9 + 0°.0138X$ | 2°.4 |
| centre | $Y' = 169°.7 + 0°.0333X$ | 1°.2 |
| following end | $Y' = 182°.2 + 0°.0299X$ | 1°.4 |

Here $X$ is measured from May 31.0, 1940.

The probability that the difference between the slopes of the Least Square Lines for each end (.0138 and .0299) is due merely to chance can be computed to be .07.[2] Such a value is not small enough to be significant, and one is hence not justified in supposing that the Red Spot did not move as a whole in 1940-41.

The $r$'s computed above may be too large for two reasons. First, an inspection of the residuals $Y' - Y$ indicates that the fundamental assumption of a linear drift perhaps was not precisely fulfilled. Second, small uncorrected systematic differences among the various observers may exist; *e.g.*, Haas' longitudes average perhaps half a degree less than Johnson's, and Vaughn's average lower still.

One may ask whether it is worthwhile to compute longitudes from transits more exactly than to the nearest whole degree. In any case one cannot sensibly go beyond the nearest half degree, since transits are timed to the nearest minute only. Using whole degrees one obtains for the centre of the Red Spot $\Sigma|Y' - Y| = 91°.4$. Using half degrees and employing the same Least Squares Line, which obviously would not be appreciably changed, one gets

$\Sigma|Y'-Y| = 94.°6$. It appears likely that using half degrees would not increase accuracy.

A question of practical importance to transit-observers is that of whether to observe the longitude $C$ of the centre of a mark or to observe the longitude $P$ of the preceding end and the longitude $F$ of the following end and average them to determine $C = (P+F)/2$. The well-known formula:

$$r^2_{f(x_1, x_2, \ldots x_N)} = \left(\frac{\partial f}{\partial x_1}\right)^2 r^2_{x_1} + \left(\frac{\partial f}{\partial x_2}\right)^2 r^2_{x_2} + \ldots + \left(\frac{\partial f}{\partial x_N}\right)^2 r^2_{x_N}$$

here becomes:

$$r_C^2 = \tfrac{1}{4}\, r_P^2 + \tfrac{1}{4}\, r_F^2$$

or:

$$r_c = \tfrac{1}{2}\sqrt{r_P^2 + r_F^2}.$$

With $r_P = 2°.4$ and $r_F = 1°.4$, there results $r_C = 1°.4$, the probable error of a longitude of the centre found from transits of the ends. The value given by observations of the centre itself is $1°.2$, as noted above. An examination of the approximate values of the probable error of a transit of different points in the Red Spot by different observers not surprisingly showed that the centre and the following end were observed about equally accurately, the preceding end, distinctly less so. (Johnson's transits are more precise than those of the other observers, perhaps because of his greater experience in observing Jupiter.) It is evident that for the Red Spot in 1940-41 it mattered little whether one observed the centre directly or found its position by observations of the ends, but it is not to be implied that this result is general.

The formula above can be used to show that if $r_P = r_F$, then there can be a gain in accuracy by observing $C$ directly *if and only if* $r_C < .71 r_P = .71 r_F$.

It will be noted that our values for the error of a transit are not unlike those found by British observers.[3]

## *Rotation Periods*

The following tables of rotation periods of particular latitudinal currents on Jupiter were based on some 2070 visual transit observations, most of them by Johnson and Haas, the reductions being made in orthodox method,[1] that of extracting periods from graphs

formed from apparently related transit observations the coördinates of which are in longitude and time. This method unfortunately rests too heavily upon the personal experience and judgment of the computer, where such variables are exercised in the choices presented for formation of said graphs. Therefore the greatest care must be observed in this work, to the point of rejecting large numbers of individually good transits because they cannot soundly be related with others. The main criteria for rejection of transit observations are two: (1) When markings in a specified current neighbour each other as closely as the order of observational probable errors or differences in personal equations attending combined group observations. Under this condition graphing is practically as impossible as it would be in random distributions. The problem is increased by the possible presence of real localized sinuosities in graphs as apart from linear or smooth curves. (2) When related transit observations lie too far apart in time. Under this condition assumed equality of rotation periods of an infrequently observed mark and a neighbouring adequately observed mark, hence parallelism of graphs, may act as a risky aid. It follows that the larger the absolute number of transits observed the larger becomes the usable per cent., and it is disheartening that many of the most interesting currents are so difficult to apprehend that the few observations made of them must remain quite untouched.

Only some 850 transits by our group, including those published elsewhere,[4] were selected for reducing the 1940-41 rotation periods. Most of the data on these should therefore be factual, but it seems inevitable that a few fictions may enter. The first column of the tables fixes an identifying number on each mark. The second column describes the most convenient physical feature of each mark whether white (W) or dark (D), and if the centre was not followed, whether the preceding end (*p*) or following end (*f*) was observed. The third column gives the limiting observational dates used for the rotation period. In order that derived periods shall not be too approximate, a minimum of 25 or 30 days for this interval was needed, but in a few special cases yet smaller intervals were considered. The fourth column reports the longitude of the mark at opposition if it was observed on or through that date, while in general marks are listed in order of increasing longitude from the

zero meridian of the appropriate System. The fifth column denotes the number of transits going to form a graph, two, the obvious minimum, being seldom tolerated. The sixth column exhibits the mean change of longitude in 30 days, followed in the seventh by the resulting rotation period. If a mark has been observed by only one person, his surname initial letter adjoins in the eighth column.

TABLES OF ROTATION PERIODS

*N.N.N. Temp. B. or S. edge N.P.R.*

| No. | Description | Dates | λ°☍ | No. Trans. | Δλ/30*d* | Rotation Period | Obs. |
|---|---|---|---|---|---|---|---|
| 1 | D | July 23–Aug. 14 | .. | 4 | −11° | 9h 55m 26s | J |

*N. Temp. Z. and N. edge N. Temp. B.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | D*p* | Oct. 13–Nov. 3 | 189 | 2 | +3 | 9 55 45 | J |
| 2 | D | Aug. 14–Aug. 30 | .. | 4 | +26 | 9 56 17 | J |
| 3 | D*p* | Aug. 19–Sept. 7 | .. | 3 | +13 | 9 55 58 | J |

*Mean.* 9h 56 m 0s

*N. Trop. Z. and N. edge N.E.B.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | D | Oct. 24–Nov. 25 | 10 | 5 | +2 | 9 55 43 | |
| 2 | W | Oct. 12–Nov. 18 | 21 | 5 | +4 | 9 55 46 | |
| 3 | W | Aug. 8–Sept. 18 | .. | 5 | −10 | 9 55 28 | H |
| 4 | W | July 10–Sept. 1 | .. | 4 | −5 | 9 55 34 | |
| 5 | W | June 28–Sept. 1 | .. | 6 | −4 | 9 55 35 | |
| 6 | D | July 13–Sept. 23 | .. | 8 | −6 | 9 55 33 | |
| 7 | W | June 26–Aug. 6 | .. | 8 | −5 | 9 55 34 | |
| 8 | W | Sept. 1–Oct. 1 | .. | 7 | −13 | 9 55 23 | |
| 9 | D | June 26–Aug. 20 | .. | 11 | −6 | 9 55 33 | |
| 10 | D | July 6–Aug. 20 | .. | 9 | 0 | 9 55 41 | |
| 11 | D | July 8–Aug. 16 | .. | 10 | + 5 | 9 55 47 | |
| 12 | W | July 8–Aug. 13 | .. | 9 | +4 | 9 55 46 | |
| 13 | D | Aug. 2–Sept. 4 | .. | 7 | −14 | 9 55 22 | |
| 14 | W | July 2–Sept. 7 | .. | 6 | −5 | 9 55 33 | |
| 15 | D*p* | Nov. 29–Jan. 11 | .. | 3 | −6 | 9 55 33 | J |

*Mean.* 9h 55m 35s

*S. edge N.E.B. and N. part E.Z.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | W | July 8–Sept. 19 | .. | 11 | −7 | 9 50 20 | |
| 2 | D | June 22–Sept. 29 | .. | 19 | −8 | 9 50 20 | |
| 3 | W | Aug. 7–Sept. 29 | .. | 10 | −5 | 9 50 23 | |
| 4 | D | July 4–Jan. 31 | 52 | 21 | −5 | 9 50 23 | |
| 5 | W | July 29–Feb. 23 | 63 | 17 | −7 | 9 50 20 | |

| No. | Description | Dates | λ°☍ | No. Trans. | Δλ/30*d* | Rotation Period | | Obs. |
|---|---|---|---|---|---|---|---|---|
| 6 | D | Sept. 30–Feb. 21 | 73 | 11 | −9 | 9 50 | 18 | |
| 7 | W | July 2–Sept. 18 | .. | 15 | −6 | 9 50 | 22 | |
| 8 | D | July 2–Oct. 7 | .. | 11 | −9 | 9 50 | 18 | |
| 9 | D | Dec. 5–Mar. 9 | .. | 8 | −6 | 9 50 | 21 | J |
| 10 | W | Jan. 11–Mar. 9 | .. | 6 | −8 | 9 50 | 19 | |
| 11 | D | July 23–Sept. 23 | .. | 13 | −12 | 9 50 | 14 | |
| 12 | W | June 30–Sept. 16 | .. | 10 | −12 | 9 50 | 14 | |
| 13 | D | June 30–Aug. 10 | .. | 7 | −8 | 9 50 | 19 | |
| 14 | D | Aug. 19–Sept. 21 | .. | 7 | −16 | 9 50 | 9 | |
| 15 | W | July 14–Nov. 13 | 169 | 19 | −7 | 9 50 | 20 | |
| 16 | W | July 14–Sept. 7 | .. | 9 | −13 | 9 50 | 13 | |
| 17 | D | June 26–Sept. 14 | .. | 17 | −15 | 9 50 | 10 | |
| 18 | W | Nov. 3–Dec. 24 | 209 | 5 | −5 | 9 50 | 23 | |
| 19 | D | Nov. 3–Dec. 24 | 222 | 5 | −7 | 9 50 | 20 | |
| 20 | W | June 19–Aug. 15 | .. | 12 | −16 | 9 50 | 8 | |
| 21 | D | Sept. 14–Feb. 6 | 237 | 11 | −2 | 9 50 | 27 | |
| 22 | W | Sept. 28–Nov. 16 | 248 | 5 | −2 | 9 50 | 28 | |
| 23 | D | July 31–Sept. 9 | .. | 12 | −13 | 9 50 | 13 | |
| 24 | W | Aug. 2–Sept. 3 | .. | 6 | −17 | 9 50 | 7 | |
| 25 | W | Aug. 2–Nov. 14 | 278 | 20 | −15 | 9 50 | 10 | |
| 26 | W | Oct. 26–Jan. 3 | 302 | 6 | −6 | 9 50 | 22 | |
| 27 | W | July 1–Nov. 28 | 329 | 22 | −6 | 9 50 | 22 | |
| 28 | D | June 29–Dec. 25 | 339 | 26 | −8 | 9 50 | 19 | |
| 29 | W | Nov. 2–Jan. 13 | 360 | 5 | −5 | 9 50 | 24 | |
| | | *Mean.* 9h 50m 18s | | | | | | |
| | | *S. Trop. Z.* | | | | | | |
| 1 | W | Oct. 26–Nov. 17 | 263 | 2 | −12 | 9 55 | 24 | J |
| | | *Red Spot* | | | | | | |
| 1 | *p* end | June 14–Feb. 20 | 161 | 44 | 0 | 9 55 | 41 | |
| 2 | centre | June 14–Mar. 14 | 175 | 64 | +1 | 9 55 | 42 | |
| 3 | *f* end | June 14–Feb. 23 | 187 | 48 | +1 | 9 55 | 42 | |
| | | *Mean.* 9h 55m 42s | | | | | | |
| | | *Red Spot Hollow* | | | | | | |
| 1 | *p* end | July 8–Jan. 13 | 156 | 13 | +2 | 9 55 | 43 | J |
| 2 | *f* end | June 19–Jan. 11 | 194 | 14 | +1 | 9 55 | 42 | J |
| | | *Mean.* 9h 55m 42s | | | | | | |
| | | *S. Trop. Dist.* | | | | | | |
| 1 | *p* end | July 3–Sept. 23 | .. | 12 | −21 | 9 55 | 12 | |

*S. Temp. B. and N. part S. Temp. Z.*

| No. | Description | Dates | $\lambda°_{\odot}$ | No. Trans. | $\lambda\Delta/30d$ | Rotation Period | | | Obs. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | D*p* | Oct. 27–Mar. 29 | 12 | 7 | −22 | 9 | 55 | 11 | |
| 2 | D*f* | July 23–Aug. 30 | .. | 4 | −21 | 9 | 55 | 13 | J |
| 3 | D*p* | Deç. 22–Jan. 11 | .. | 3 | −29 | 9 | 55 | 2 | J |
| 4 | D*f* | Aug. 2–Nov. 17 | 274 | 9 | −22 | 9 | 55 | 10 | J |
| 5 | D*f* | Feb. 16–Mar. 14 | .. | 5 | −15 | 9 | 55 | 20 | J |
| | | *Mean.* 9 h 55m 11s | | | | | | | |

*S. part S. Temp. Z. and S.S. Temp. B.*

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | D*p* | Oct. 27–Nov. 16 | 127 | 2 | −29 | 9 | 55 | 2 | J |
| 2 | D | Jan. 3–Feb. 10 | .. | 5 | −25 | 9 | 55 | 7 | J |
| | | *Mean.* 9h 55m 5s. | | | | | | | |

REMARKS. *N.N.N. Temp. B or S. edge N.P.R.* Of 22 transits, all pertaining to large, indefinite, and longitudinally extended dark spots, only these four could be utilized. On November 3, Johnson confirmed "a previous impression: that condensations here [in the N.P.R.] usually are not alone, but have one or more others accompanying them stacked in higher latitudes *diagonally, with those in higher latitudes also in higher longitudes.*"

*N.N. Temp. B.* Of 22 transits of condensations and *p* or *f* end dark sections, Peek[5] has used four by Johnson as an aid in establishing the recurrence of short rotation periods first followed here in 1929-30. Peek's mean period for three spots is 9 h. 54m. 2s. None of our other transits furnishes a rotation period, but the following transits by Johnson of the *p* end of one or more dark sections (sometimes seen in the N.N. Temp. Z.) might be significant were their dates not so far apart.

| | |
|---|---|
| July 20 | 115½° |
| August 13 | 113 |
| October 13 | 115 |
| October 27 | 117 |
| November 28 | 115 |
| January 5 | 116 |

*S. edge N. Temp. B.* Johnson[4] has already discussed 158 transits of dark spots giving 16 rotation periods with a mean at 9h. 49m. 14s. and demonstrating the continuation of this well known "abnormal" current since a 1939 outbreak.[6]

*E.B. and N. edge S.E.B. N.* Nearly 60 transits of condensations in these latitudes had to be discarded, being too widely scattered.

*S. Trop. Z.* We omit those few of our transits which pertain to a remarkable dark spot at the N. edge of the S. Temp. B. discussed by Peek[7] using a larger set of his transits. He found that "a damped harmonic oscillation in longitude is very closely represented by the observations."

*Red Spot and Hollow.* The data for the Red Spot were derived from the Least Square Lines of the previous section. The intensity of the Spot was not great, perhaps usually weaker than in 1939-40 but strong enough to permit its detection by Johnson on one occasion with his unsilvered 7-in. reflector. On several nights Johnson thought that one or both ends of the Spot were rather sharply pointed. The Red Spot Hollow was definitely fainter than in 1939-40 and though of similar form was 38° long as against 28° in the preceding apparition.[1]

*S. Trop. Dist.* In view of apparent British failure[5] to see this mark we give below in detail the observations yielding our rotation data, these being the only clearly related set of transits among a larger group of *p* ends of *very* faint S. Trop. Z. shadings.

| | | | |
|---|---|---|---|
| July | 3 | 134½° | Johnson |
| | 8 | 133 | " |
| | 25 | 132 | " |
| August | 4 | 123 | Haas |
| | 6 | 122 | " |
| | 13 | 118 | Johnson |
| | 18 | 115 | Haas |
| September | 4 | 106 | " |
| | 6 | 101 | " |
| | 16 | 94 | " |
| | 18 | 89 | " |
| | 23 | 77 | " |

These indicate an accelerating motion and a rotation period shorter than any in the 1901-33 interval according to the Jupiter Section of the British Astronomical Association.[8] The July 3 position is near that which might be expected from an extrapolation of the longitudinal drift of the previous apparition, an extrapolation made uncertain by peculiar 1939 motion and required passage through the Red Spot region in early 1940. No trace of the general body of the Disturbance or its *f* end could be made out.

*S. Temp. B. and N. part S. Temp. Z.* Spot No. 5 may be identical with No. 4.

*S.S. Temp. B. and S. part S. Temp. Z.* Spot No. 2 on January 3 and 5 was perhaps the darkest mark on the planet, showing as an elongated condensation in the S.S. Temp. B. On January 27 it had faded to an intensity not fainter than the S. Temp. B. and was enlarging northward. By January 29 it had become a distinct spot in the S. part of the S. Temp. Z., as it remained on February 10 when it appeared to cause a "slight depression in the S. edge S. Temp. B." at the same longitude.

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W. H. Haas, New Waterford, Ohio.
H. M. Johnson, 126 Albemarle Street, Rochester, New York.
March, 1943.

# THE JOVIAN TRANSIT OBSERVATION PROBLEM AND AN INSTRUMENTAL SOLUTION

By Hugh M. Johnson

FOR three centuries an observational method in visual planetary astronomy has remained virtually unchanged. This is the practice of timing transits of markings displayed by members of the solar family across eye-estimated central meridians for the determination of rotation data. Where constancy of rotation period and fixity of reference detail may be relied upon the method becomes powerful with lapse of time, irrespective of the accuracy of individual observations. But in the vastly more interesting cases where these two conditions are not met the accuracy of the individual observations demands more attention if the method is not to degenerate to impotent approximation. Justification for engaging with this matter now lies chiefly in its applications to the planet Jupiter which for a half-century has been the only body attracting systematic transit study, notably by British amateurs. Contemporaneously the brilliant results of solar and sidereal spectrography evidently paled planetary physics dependent upon such relatively weak investigatorial means, but in recent years B. M. Peek[1] has been ingenious in employing visual transit observations as a basis for new theoretical hints about the physical state of the largest planet. This work seems to promise future development, and it should be stimulating if only because it enters upon unexplored ranges of celestial physical conditions perhaps unattainable in the laboratory.

Visual transit work is subject to several sources of error. Error in timekeeping or recording is rarely excusable with required accuracy to the nearest minute only. Observations usually pertain to "centres" of markings, but where there is diffuseness, or irregular shape, particularly asymmetry with respect to a meridian, or excessive extension in longitude, it is obviously difficult for the eye to define such points. The inability of the eye to place exactly the central meridian on the telescopic image, however, is the chief

[1] *E.g., Jour. Brit. Astron. Assoc.*, vol. 50, p. 4, 1939; *Monthly Notices R.A.S.*, vol. 101, p. 70. 1941.

failing of the present transit method, and it is to the remedy of this that we here try to proceed. We therefore shall attempt to diminish, *e.g.*, accidental errors, personal equation, a likely effect of apparent exaggeration over geometrical phase, and any effects of the character of detail neighbouring the central meridian, of this origin. As was long ago suggested, it would seem that the filar micrometer should deal adequately with the situation, but closer scrutiny reveals inopportunities. An excellent clock-drive is needed but often not had. Worse, not only the opaque wires but diffraction at their edges obliterates much fine detail near the critical region. What is needed, therefore, is a sufficiently narrow, transparent, artificial central meridian, mobile with the image of the planet.

Arrange the following separate elements with optical axes coinciding with that of the telescope in order away from the objective. First a concave lens lessening the convergence of part of the cone of rays proceeding from objective to focus. Second and third, cylindrical lenses convex about an axis parallel to the rotation axis of the planet intercepting different parts of the secondary cone of rays just established and bringing said rays to a focus coinciding with that of the telescope. We thereby form two luminous reference lines which, upon being made to coincide as when the optical axis intersects the central meridian of the visible illuminated part of the planet, determines the desired artificial central meridian. It is not to be expected that this may be done without impairing the normal efficiency of the telescope, but perhaps the least damage will be done if the lenses are annular, hence acting as marginal aperture stops reducible to little consequence. At the same stroke we remove the core of the difficulty of correction of zonal aberrations, the chromatic aspect of which may be further mitigated by the use of coloured glass for, say, the first element, as there should be no objection to monochromatic lines. The lines will be different in width, each of them bearing a ratio to the apparent equatorial diameter of the planet equal to the ratio of the focal length of the respective cylindrical lens to that of the telescope. This dissimilarity should not interfere with attaining their coincidence if both are kept sufficiently narrow, a desideratum which may not be

pushed too far, however, without threatening the objective aperture too much or without incurring an inappreciable differential displacement of the lines with images off the optical axis.

The theoretical dimensions of this instrument for a given telescope should not be difficult to resolve, but the problems of practical construction for the amateur may be great. Owing to the infrequence of use in precision optics there is little or nothing in the literature on the working of cylindrical surfaces, particularly of the quality perhaps here demanded. This may only 'whet' the interest of the optician. The process will surely involve complementary cylindrical grinding tools which must later be polished with the lenses and transformed into surfaces for tests by interference. By reversals, or utilization of the two fits of such surfaces, their regularity may be noted and coniform tendencies checked. Though there is no control over probable toric tendencies, these will not be harmful unless gross, merely causing some departure in the length of the line image from equivalence with the polar diameter of the image. The working of an annulus is a feat better avoided by retaining the interior for the while. If the optical surface is not continuous, *i.e.*, if the interior has been removed and replaced, much care will have to be devoted to the critical inner edge of the annulus which may "turn down:" it must be quite "sharp" in the interference test. Any tests of individual elements should be supplemented by the more or less empirical guide of lenses mounted in conjunction with the actual telescope.

126 Albemarle Street, Rochester, New York
August 8, 1943

# AIR CURRENTS WITHIN THE REFLECTOR TUBE

By E. K. White

PRESENTED in this article are the results obtained from experiments made with an electric fan forcing a current of air into the metal tube of a Newtonian reflector.

The telescope is of 9 inches aperture, and 100 inches focal length, and is used chiefly for the study of lunar and planetary detail. The tube is of iron, 10 inches in diameter, and 104 inches long. There are no ventilation holes in the tube, save for a narrow space between the wall of the lower end of the tube and the mirror cell. When not in use the instrument is housed in a roll-off wooden shelter.

It is well known that many observers are of the opinion that closed metal, and even closed wooden, tubes have a detrimental effect on the seeing; the reason being assigned to the presence of air currents within the tube of a different temperature from that of the outside surrounding air. Possibly the best remedy is an open skeleton-type tube, similar to those of the large reflectors. However, one living in a damp climate, as prevails in most of southern British Columbia, will have severe dewing and frosting conditions to contend with unless the mirror is removed to the house when not in use; and this method is bad for the silver film. The closed tube insures freedom from dewing of the mirror and prevents trouble from stray light, also it aids in keeping the mirror free of frost crystals in winter.

The late W. H. Pickering,[1] well known lunar and planetary observer, claimed greatly improved seeing with closed tube reflectors by forcing a stream of air through the tube, introducing it by means of a small fan near the mirror's surface, and expelling it out the open end. Here is movement of air within the tube, but of the same temperature as that outside. In other words, the troublesome warmer or colder air in the tube is displaced by outside air. Of course the fan must be kept running as long as observations are made.

By way of experiment, a round hole 5 inches in diameter was cut in the lower wall of the tube, just above the surface of the mirror. This is covered by a metal hinged door, having a close-fitting felt gasket. A 5-inch electric fan was obtained and experiments started.

At the beginning of observations the extra-focal rings of a bright

[1] "Amateur Telescope Making, Advanced", page 610.

star, usually Polaris, were noted. Immediately the tube door was opened these rings became much distorted and unsteady. When the fan was started the rings became circular again and steadier, but they always showed a rapid rotation in the direction of the fan blades. With the fan running, the rings were definitely steadier than when the fan was off but the door open.

The definition of detail on the moon and the planets Saturn and Jupiter was studied, with and without the fan, in all conditions of seeing the skies afforded. It was impossible to note any improvement with the fan on these objects, when the seeing was between 0-4.[2] However, on a few occasions when seeing was estimated to be from 5-7, a very slight improvement in definition seemed certain when using the fan. The floor of the lunar crater Plato under oblique lighting was used as a test, and on good nights from two to four craterlets could be seen as such. With the fan running, these marks were steadier although no more fine detail could be seen than before. No further detail could be seen on the planets mentioned, simply a steadying of the difficult marks seen without the fan. No improvement could be noted in the resolving of close double stars in any condition of seeing, but little time was spent with this particular investigation.

The fan must be mounted on an adjustable stand, and not attached to the tube, so as not to set up any vibrations in the instrument. The blades should be kept close to the tube opening, in order to have a maximum current of air flowing through it. These requirements introduce some inconvenience in any careful observing program by necessitating rather frequent adjustments of the fan as the drive carries the long tube forward.

From results so far obtained, with the exception of rare nights when seeing is quite good, the use of a fan is not considered worth while as a measure to improve definition. While it is known that other observers than W. H. Pickering have claimed that the use of a fan gives marked improvement in definition, I have unfortunately been able to find little published of their findings, or methods. Further experiments with a fan are being continued at this station.

Chapman Camp, B.C.
October 1943

[2]Scale of seeing devised by W. H. Pickering—0 very poor, 10 excellent.

## REVIEW OF PUBLICATIONS

*Atoms, Stars and Nebulae* by Leo Goldberg and Lawrence H. Aller. 323 pages, 5½ x 8½ in., 150 figures. Philadelphia: Blakiston, 1943. Price $2.50.

This is another of the well-known Harvard Books on Astronomy. The authors of the present volume certainly attempted a difficult task. In it they aim to give a clear, understandable outline of the modern theory of atoms and molecules and then, by means of it, to account for the multitude of intricate phenomena met with in the study of the radiation from the stars and nebulae which people the depths of space.

In the first chapter the reader is made acquainted with the stars and the nebulae, including how the stars are weighed, the nature of eclipsing binaries and the mass-luminosity law. In the next chapter the use of the spectroscope is explained, and then follows a rather technical explanation of the way atoms radiate light. Reference is here made to neutrons, protons, electrons; the nature of the nucleus; atomic numbers and atomic weights; Balmer's series, Bohr's model, ionization potentials; complex atoms, spinning electrons; wave atoms —and other things. The book is intended for the intelligent layman, but he must not expect to read the 21 pages of this chapter in as many minutes and know anything about the wonderful things discussed therein. He will have to concentrate on it and perhaps fortify his knowledge from other books.

The following chapters deal with: the climate in a stellar atmosphere; dwarfs, giants and supergiants; analysing the stars; pulsating stars; exploding stars; the planetary nebulae; between the stars; stars with extended atmospheres; and, what makes the stars shine?

It must be acknowledged that in the last score of years the investigation of astrophysical problems has given rise to an abundance of theory, hypothesis and speculation. Probably many of our conclusions regarding the nature and structure of those intriguing points of light a thousand or a million light-years away would be found very different from actuality if one could only travel far out to see just

what they are like. What will our successors fifty years hence think of some of our fantastic ideas?

However it is really marvellous what deductions can be made from a searching scrutiny of the lines in the spectrum of a heavenly body and the authors endeavour to state clearly what conclusions have been reached. To give a full statement of the process by which some of these results have been obtained would be more satisfying to the scientific mind, but the limitations of the aims of the book would hardly allow that. The reader, whether a professional or an amateur student of science, will find here a good outline of modern astrophysics stated more fully, clearly and authoritatively than in any other elementary work.

For the more serious student a 30-page appendix is added giving a list of astronomical constants, and various mathematical formulas with examples of their use.

C. A. C.

# NOTES AND QUERIES

**Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.**

## Centenary of the Cincinnati Observatory

The American Astronomical Society at its 71st meeting, held in Cincinnati, Ohio, November 5-7, 1943, assisted in commemorating the one-hundredth anniversary of the founding of the Cincinnati Observatory. In *Science* for October 22 is an interesting sketch of the Observatory, a portion of which follows:

The corner-stone of the observatory, the first to be erected in the United States, was laid on November 9, 1843, by John Quincy Adams, sixth president of the United States. The original telescope was for many years the largest in the United States and second in size only to an instrument in the Royal Imperial Observatory at Poulkova, Russia. This 11-inch glass is still in constant service.

Ormsby MacKnight Mitchel, professor of natural philosophy, mathematics and astronomy at Cincinnati College, forerunner of the University of Cincinnati, was the founder of the observatory, virtual builder of its original structure and purchaser of the telescope. Professor Mitchel quarried his own stone, dug his own sand, burned his own lime, dammed a small stream of water, supervised construction of the building and served without pay for two decades. Ground was donated by Nicholas Longworth, grandfather of the late Speaker of the House, Nicholas Longworth, a graduate of the university, on Mount Adams, a Cincinnati hill-top. The observatory was moved in 1873 to its present site on Mount Lookout, several miles farther from the downtown area.

Professor Mitchel was the first director, serving until the Civil War. In 1846 he began the publication of the monthly *Sidereal Messenger*, the first astronomical periodical in the United States. He was succeeded by Professor Cleveland Abbe, who inaugurated a system of telegraphic weather reports which aroused such interest that the U.S. Weather Bureau organized the same service on a nationwide scale.

At the present time it may be interesting to give the following information regarding this historic institution. It is from "The Recent Progress of Astronomy, especially in the United States" by Elias Loomis (1851), pages 182-4:

The *Cincinnati Observatory* owes its existence to the labors of Prof. O. M. Mitchel. In the years 1841 and 1842, a society was organized in Cincinnati, called the Cincinnati Astronomical Society, the object of which was to furnish the city with an observatory. Eleven thousand dollars were subscribed in shares of twenty-five dollars; and a site for the observatory was given by Nicholas

Longworth, Esq. It consists of four acres of ground, on one of the highest hills on the eastern side of the town. In June, 1842, the society being fully organized, Professor Mitchel visited Europe to purchase a telescope. At Munich, he found an object glass of twelve inches aperture, which had been tested by Dr. Lamont, and pronounced one of the best ever manufactured. This was subsequently ordered to be mounted, and was purchased for $9,437. The instrument arrived in Cincinnati in February, 1845. In November, 1843, the corner-stone of the observatory was laid by the venerable John Quincy Adams. The building is eighty feet long and thirty feet broad. Its front presents a basement and two stories; while in the center, the building rises three stories in height. The pier is built of stone, and is grouted from its foundation on the rock to the top. The equatorial room is 25 feet square, and is surmounted by a roof so arranged as to be removed entirely during the time of observations.

The object glass of the telescope has an aperture of twelve inches, and a focal length of 17 feet. The hour circle is 16 inches in diameter, and reads by two verniers to two seconds. The declination circle is 26 inches in diameter, and divided on silver to five minutes, reading by verniers to four seconds. The instrument has five common eye-pieces and nine micrometrical, with powers varying from 100 to 1,400.

Quite recently, through the kindness of Dr. Bache, the superintendent of the U.S. Coast Survey, this observatory has been furnished with a five feet transit instrument, which is now mounted and in active use. A new sidereal clock has recently been presented to this observatory.

Professor Mitchel has hitherto devoted his time chiefly to the remeasurement of Struve's double stars south of the equator. This work was undertaken at the special request of that distinguished astronomer. Quite a number of interesting discoveries have been made in the course of this review. Stars which Struve marked as *oblong,* have been divided and measured; others marked *double,* have been again subdivided and found to be *triple*; while a comparison of the recent measures of distance and position with those of Struve, has demonstrated the physical connection of the components of many of these southern stars.

Pasted in a copy of the above-mentioned book by Loomis in the Library of the David Dunlap Observatory was found a printed letter dated August 18, 1869, written to *The Leader,* a Toronto newspaper of the period, by D. K. Winder, one of the earliest of Toronto amateur astronomers. In it he describes a visit to the Cincinnati Observatory. Two paragraphs are quoted below:

Professor Cleveland Abbe, the present director, took charge of the Cincinnati observatory in June, 1868, and as he is a gentleman of learning and energy, as well as a reliable observer, the public may expect to hear a good report from the great refractor, notwithstanding the many disadvantages the

Professor labors under, owing to the want of repairs the building needs, and the lack of several important instruments.

The reader will be pleased to hear that the great telescope is still in very good condition, and working well. The object glass is 11½ inches in diameter, and 17½ feet focal distance; it was made by Frauenhofer, and perhaps, is his *chef d'oeuvre*; it was purchased, together with the equatorial mountings, in Munich, Germany, in 1844, at an expense of nearly ten thousand dollars. At the time it was mounted, there was but one larger telescope in the United States, and but two larger in the world.

Some personal details of Ormsby MacKnight Mitchel are extracted from the *Monthly Notices of the R.A.S.*, vol. XXIII, p. 133, 1862:

Professor Mitchel was born on the 28th of August, 1810, in Union County, Kentucky. At an early age he gave promise of the ability and eminence which his future so fully realized. He was appointed a Cadet in the U.S. Military Academy in 1825. He graduated with distinction in 1829, and was very soon appointed Assistant Professor of Mathematics, which post he held for two years. He subsequently resigned his commission in the Army, and, after practising Law for a short time, he accepted the chair of Mathematics and Astronomy in the Cincinnati College, Ohio, in which position he continued for ten years.

It was here that he commenced a series of lectures; and those which he delivered on the physical constitution and telescopic appearances of the planets created so vast an enthusiasm, that it was resolved to furnish the city with a large telescope forthwith. Subscriptions for this purpose poured in from all quarters; and as specie was not always at hand, there were not a few contributions in kind, such as hats and caps, and other unastronomical apparatus. Mitchel then proceeded to England in quest of his telescope, and was there introduced to the Astronomer Royal by John Quincy Adams. At his earnest request, Mr. Airy allowed him to go through the greater part of the Greenwich course; and for some time he worked as a computer at one of the Royal Observatory desks. On his return home, the population of Cincinnati assembled, in the largest church of the place, to hear the account of his mission. The first-fruits of Mitchel's labours with his large equatoreal was the discovery of the companion of *Antares*. But, inasmuch as a rival telescope at another place, owing to an idiosyncracy of its object-glass, showed two companions instead of one, the ill-fated Astronomer and his Observatory were shorn of their glory and their subscriptions besides. After this, the Professor was concerned as Projector, Director, and Engineer, in "building" certain Railways; and it is hoped he realised a good fortune thereby. He was in England a second time for the sale of railway bonds.

Professor Mitchel, when a Major-General in the Federal Army of the United States, died of fever at Beaufort, South Carolina, on October 30, 1862, after an illness of only four days.

C. A. C.

# MEETINGS OF THE SOCIETY

## AT TORONTO

*March 16, 1942.*—The meeting was held in the McLennan Laboratory, University of Toronto, at 8.00 p.m.; Miss R. J. Northcott in the chair.

Two candidates were duly elected to membership in the Society, viz:

Mr. Israel Gang, 25 Rains Avenue, Toronto, and

Mr. Vincent Kerr, 759 Kingston Road, Toronto.

Dr. A. M. Crooker, physicist at Research Enterprises Limited, Leaside, spoke on "Military Telescopes—How They are Made and Used." Ordinary glass had been known since Biblical times but optical glass was slightly more than 100 years old, he said. Neither Galileo's telescopes nor those of several generations of astronomers after him were of optical glass.

Manufacture of optical glass was an European monopoly until the last war when the industry was started in the United States. The first optical glass produced in Canada is that being turned out by Research Enterprises Limited, a government-owned corporation started since the outbreak of the present war. World production of optical glass comprised less than one-tenth of one per cent. of total glass manufacture.

The making of optical glass is a blend of art and science. Chemically pure materials and carefully controlled methods are required to obtain the high quality glass desired for war purposes. The pots, carefully dried for several months after they are made, are pre-heated at 800°C. for a week before they go to the firing furnace. Then, at 1400°C., they are glazed with waste glass before the batch of chemicals is poured in. The mix, when molten, is stirred for hours with a clay rod cooled with flowing water. When taken from the furnace the clay pots are cooled slowly and then smashed with a sledge hammer. The mass of glass breaks along natural fractures and the pieces are carefully sorted, only those without flaws being used for optical instruments.

The selected pieces of glass are cut, softened to plastic state in open furnaces, and stamped into approximately the size and shape desired for the final processing. After annealing, polishing and centring, these pieces are passed on as lenses or prisms to the assembly departments.

Dr. Crooker also described how optical instruments are designed for various uses in the armed services. As a rule, he said, there is a lapse of four to six months between the blueprint and actual production of a new instrument. Many types of instruments are being made for Canadian and Allied forces, but for most purposes the services preferred those having a large exit-pupil (ratio of aperture stop to magnification). Despite resulting small magnification, this type had the advantage that the observer could keep the image in sight even when riding, for instance, on a roughly moving tank or field car.

Dr. Helen S. Hogg in the fourth paper in the series on "Major Advances of the Twentieth Century in Astronomy," spoke on "Big and Little Stars—The

Russell-Hertzsprung Spectrum-Luminosity Diagram." The terms "giant" and "dwarf" were applied to stars by Hertzsprung who in 1905 showed that some red stars were evidently larger and brighter than others of the same spectral type, but that there was no intermediate luminosity. In 1913, H. N. Russell made a diagram of stars for which both spectral types and absolute magnitudes were known. This supported Hertzsprung's suggestion that red stars were either very bright or very faint. Yellow stars could be intermediate, while blue stars were always bright.

Russell's theory suggested that a star begins as a mass of gas drawn together into a more or less compact form by mutual gravitation; when the mass becomes dense enough to produce sufficient pressure the temperature rises. The mass eventually becomes sufficiently dense and hot to emit light as a giant red star of M-type. The density and temperature continue to increase as the star progressively changes to K, G, F, A and possibly B-type. At some point along the evolution diagram for each star the density becomes so great the radiation exceeds the amount of heat developed by contraction, and the star begins to cool and shrink, moving through B, A, F, G, K and M spectral types on the dwarf "main sequence" side of the diagram. In some cases when the star's mass is small, the maximum giant stage is reached at an intermediate spectral class and the star then begins to descend to a high-density red star of low temperature.

Eddington, in his mass-luminosity law, stated that a star's brilliance is a direct function of its mass. It is now admitted that the sun and stars shine at the cost of some of their material; that in their hot interiors matter is transformed into energy, apparently by means of the carbon cycle of internuclear reactions. The sun is radiating mass at a rate of 4,200,000 metric tons a second but billions of years would be required to reduce its mass by a few per cent.

The largest stars known are cool red giants, such as Antares (diameter—430,000,000 miles) with low surface temperature. Their extraordinary low densities (Antares, 0.0000003) are comparable to earthly vacuums while their masses are several times the sun. The smallest and coolest stars known are the red dwarfs with masses only a fifth of the sun. Due to their low luminosity it is impossible to estimate what proportion they comprise of the total number of stars. Our sun is roughly half way down the "main sequence" from the intermediate blue (B-type) to the red dwarf stage.

One of the greatest anomalies disclosed in 20th century astronomy is the existence of white dwarf stars, a small group which stands off from the Russell-Hertzsprung diagram. Very small, of planetary dimensions, they have a mass equal to the sun and very high surface temperatures. First discovered of the group and best known is the Companion of Sirius, with a density 40,000 times that of water. Since the heaviest metals on earth are only 20 times the density of water, these stars must be composed of atoms stripped of electrons down to their nuclei. A pint of the material in the Companion of Sirius would weigh 20 tons. Other white dwarfs discovered by van Maanen and Kuiper have densities several million times that of water. More than 12 white dwarfs are now known but whether they are a rare occurrence or a common stage in the evolution of stars is still uncertain.

*March 30, 1943.*—The Society met at the usual hour and place, Miss R. J. Northcott in the chair.

Mr. Douglas Royden Garrett, 59 John Street, Weston, Ont., was duly elected to membership in the Society.

Dr. A. E. Johns, McMaster University, Hamilton, first vice-president of the Society, addressed the members and visitors on "Order is Heaven's First Law."[1] There is complete order in the universe from the smallest units, the electron, atom and molecule, to the largest, the planet, star and galaxy, he said. "If Nature were not orderly, all Science would be hopeless, because Science is based on the belief the universe is orderly."

Newton was clearly convinced of the rule of law everywhere. Even the early philosophers recognized the *saros* as a factor in the repetition of eclipses. This was determined so far back in history there is no record of its origin.

The Chaldean and Babylonian astronomers only made observations; the Greeks were the first to base theories on the phenomena they observed. A few of the more important names in Greek contributions to astronomy are Thales, Pythagoras and his followers who believed the earth a sphere, Apollonius who suggested the epicycle for planetary motions and developed the theory of conic sections, Hipparchus—"Father of Astronomy"—who further developed the idea of epicycles and introduced the eccentric, Ptolemy, and Aristarchus who put the sun at the centre of the universe and made the earth rotate and revolve, an idea not accepted until 14 centuries later when Copernicus reintroduced it.

Nicholas Copernicus made the first step forward by displacing the earth as centre of the solar system, putting the sun in its place, and obviating need for the complex epicycles. He died 400 years ago (May 24, 1543) just too soon to feel the terrific repercussions, particularly in religious circles, stirred up by his suggestion. Copernicus still kept the circular orbit for the planets, the elliptical orbit being introduced later by Kepler along with his laws of planetary motion. Newton's law of gravitation which came later was a "marvellous law,"—one which has kept mathematicians and astronomers busy ever since working out its consequences, Dr. Johns said.

Dr. Helen S. Hogg in the fifth paper in the series on "Major Advances of the Twentieth Century in Astronomy" spoke on "Pulsating Stars, and the Period-Luminosity Relation." All intrinsic variable stars whose light output is actually changing (not eclipsing binaries) with periods of less than 50 days are called Cepheid variables, a name derived from the prototype star, $\delta$ Cephei. Cepheids with periods of less than one day are designated cluster-type because they are found in large numbers in the globular clusters. Typical Cepheid variables with periods greater than one day have a range of about one magnitude ($2\frac{1}{2}$ times) in light and a continuous variation with great regularity. The maxima of the star may be predicted years ahead to within a minute or two once the period has been determined. The colour (temperature) changes, the star being redder at

[1]Dr. Johns' paper is published in this JOURNAL, vol. 37, no. 6—July-Aug., 1943.

minimum light than at maximum. The spectroscopic radial velocity varies during the cycle of light changes indicating expansion. Cepheid variables are supergiant stars—among the most luminous known—and thus can be seen at greater distances than normal stars. The brilliance of $\delta$ Cephei is 700 times that of the sun. Rare in space, Cepheids probably comprise only one star in a million.

In 1912 Miss Henrietta Leavitt at Harvard Observatory, working on photographs of the Small Magellanic Cloud taken at Arequipa, Peru, determined the periods of several Cepheid variables which by reason of their location in the cloud were known to have the same approximate distances. She found that the longer the period, the brighter the Cepheid, and from these data a curve was prepared to give absolute magnitude of any Cepheid of known period. This is known as the period-luminosity relation. This has provided a yardstick for the universe and the scale of distances for the whole universe is based largely upon it. Once the period of a Cepheid, easily visible at great distances, is determined the curve indicates the absolute magnitude of the star. The apparent magnitude is easily measured, and the distance then computed. Cepheids have been identified in the most distant parts of the galaxy, in the fringe of the globular star clusters, in the Magellanic Clouds, Andromeda Nebula, Triangulum Nebula and other extragalactic nebulae. Even a few Cepheids in a cluster or nebula are enough to permit determination of the distance.

Cepheids are thought to be stars alternately contracting and expanding, according to the current theory proposed by Shapley and Eddington which fits all observational data. According to Eddington: "First there is a small pulsation. When compressed the star has higher temperature and density than usual and the tap of sub-atomic energy is opened more fully. The star gains heat and the expansive force of the extra heat assists the rebound from compression. At greatest expansion the tap is turned off a little and the loss of heat diminishes the resistance to the ensuing compression. . . . The only objection that I can find to this explanation is that it is too successful. . . . Stars in general do not pulsate. . . . Cepheid pulsation is a kind of distemper which happens to stars at a certain youthful period; after passing through it they burn steadily."

*April 13, 1943.*—The Society met at the usual hour and place; Miss R. J. Northcott in the chair.

Six candidates were duly elected to membership in the Society, viz:

F/O. William F. Hunt, 7 Bloomfield Avenue, Toronto; Mr. D. A. Ross, 116 Spencer Avenue, Toronto; Mr. Fred B. Conron, Royal Bank Building, Toronto; Mr. Charles Hart, 13 Nairn Avenue, Toronto; Mr. James E. Harvey, 30 Earl Street, Toronto; and Mr. James E. Schnell, 274 College Street, Toronto.

Dr. E. S. Moore, Professor of Geology, University of Toronto, addressed the Society on "The Constitution of the Earth as a Geologist Sees It." A synopsis of the paper follows:

It is necessary in any consideration of the constitution of the earth to give some thought to the nature of the materials that accumulated to form it and their mode of accumulation. Here the geologist and astronomer meet, for the geologist is dependent upon the astronomer to account for the events that led up to the

accumulation of the materials that compose our planet. The astronomer must also explain the effect of external forces and conditions that maintain it in its present state as a member of the solar system. The geologist leaves to the astronomer the explanation of where and how the materials for the solar system and other heavenly bodies appeared in the first instance.

Even in his so-called practical work, the geologist is accustomed to employ theory to quite an extent. It is necessary to employ even more theory and speculation to the problems of the earth's interior. Professor R. A. Daly of Harvard in a recent article quotes a leading physicist as saying "the problem of the earth's interior is fantastically difficult," and a distinguished geologist as suggesting "the deep interior should be left to the poets."

*Available data on the earth's interior:* It is estimated that the average composition of the crust is approximately 46.5% oxygen, 27.6% silicon, 8% aluminium, 5% iron, and so on, with 18 elements making up 99.5% of the total. This leaves out many common metals like gold, silver, copper, lead, zinc, tin and even nickel. . . . Our deepest mines are down to 8,500 feet and our deepest oil wells to a little more than 15,000 feet. Gold is being mined in India that was probably formed at a depth of 20,000 feet. Removal of overlying rocks by erosion has exposed it at the present surface. . . . We have rocks now at the surface that may have been buried to a depth of 50,000 to 60,000 feet and brought up by deep folding and faulting in mountain ranges and then exposed by erosion. Some igneous rocks in liquid condition have probably come from even a greater depth. All of these depths are really very superficial when compared with the radius of the earth.

The earth's temperature increases, according to Gutenberg, about one degree Fahrenheit for each 90 feet in depth. The figure is much lower for some of the geologically ancient areas that are highly stable like the Precambrian shields where it may be as low as 200 feet per degree. It is much higher in some areas of recent volcanic activity, local chemical action or physical adjustments where friction due to movement is a factor. It is believed this rate of temperature increase is not maintained all the way to the centre but in any case the interior is regarded as very hot—hot enough to melt any of the substances known at the surface. Daly thinks the temperature is too high for any rocks to crystallize below 90 km., but according to physicists the earth as a whole is as rigid as steel and very slightly deformed by tidal action. Pressure is no doubt an important factor in this matter. . . . The pressure at the centre has been computed at about 3,500,000 atmospheres or 50,000,000 pounds per square foot. We have not much idea of just what such a pressure would do to any of the rocks with which we are familiar if they were at the same time exposed to the temperature existing in the deep interior.

The earth's density is computed at 5.52 that of water while the specific gravity of the rocks at the surface is about 2.7 on the average which leads to the conclusion that the interior either consists of much heavier materials than those in the crust or the same materials are in some state quite different from that at the surface. . . . Isostasy, the balancing of one segment of the crust against

another, supplies considerable data regarding the lower portion of the crust. Pendulum measurements on gravity of the different sections of the surface show that segments of the earth's crust float, so to speak, nearly at a level corresponding to the relative weights of the segments. Oceanic segments are heavier and float at a lower level than the continental segments which are composed of lighter rocks. The continental masses consist very largely of the acid rocks, like granite, while under the ocean the rocks are mainly of the dark, basic, heavier kind, as seen in the rock extruded from the submarine volcanoes in the Pacific basin.

In spite of the apparent strength of solid rocks the earth's crust is rather delicate when considered in connection with the great forces that operate in it. The surface rises and sinks rather readily with the shifting of weight from one area to another, as when large quantities of sediments are eroded from mountains and deposited in the sea. The weight of the ice-sheets that covered Canada in the Pleistocene was sufficient to depress the eastern part of Ontario below sea level, Marine beaches on the Ottawa River stand over 600 feet above sea level to-day, showing that when the ice melted away the land rose again to that height. This teetering up and down of segments of the crust accounts for our continents and oceans. It is evident that in spite of all the elevations and depressions of the surface the oceanic and continental segments have maintained their relative position throughout at least most of geological time. We find plenty of sediments that were deposited in the shallower parts of the oceans now raised high above the sea, and shallow seas have invaded the continents on many occasions, but we have never found any of the particular type of very deep-sea deposits on the land surfaces.

The difference in weight between the oceanic and continental segments is believed to be the source of the force that builds our great mountains and heaves up the plateaus. Isostatic adjustment is considered as pertaining to a depth above a level of about 40 miles. Below this level there are zones believed to be homogeneous insofar as materials composing them are concerned and which respond mainly as units. There is not complete isostatic adjustment in all parts of the crust or in all parts of any continent—some mountains stand a little higher than they should to be in perfect adjustment; some areas are lower than they should be. This may be explained as being due to differences in the strengths of the rocks; some yield readily to stresses, others do not. The arrangement of rocks in the crust may also partly account for the situation. Time is an important factor in the deformation of rocks.

*The testimony of earthquake vibrations:* Study of the velocity of earthquake waves passing through the earth has supplied data that convince us that the earth is composed of zones or shells of material differing considerably in composition. At a depth of about 70 km. there is a sudden increase in velocity of the waves. A minor increase occurs between 400 and 480 km. and a marked increase between 480 and 950 km. There is some decrease in velocity between 950 and 2700 km. A very striking decrease occurs at about 2800 km. where it is believed the iron core of the earth begins. Here the longitudinal wave drops in velocity from about 16.3 km. to 8.1 km./sec. and the secondary wave fades out. . . .

Earthquakes are generally due to faulting, fracturing of rocks and shifting of large masses, jarring the crust, thus setting up vibrations that travel through the earth. We used to think that the foci of all earthquakes lay within about 30 miles of the surface. Now any earthquake with a focus less than 40 miles deep is called a quake of shallow focus, and some quakes are believed to have foci as deep as 300 miles. It is difficult to conceive how a shock can originate in material that is believed to act as a plastic substance and not be subject to the effect of strain.

*The role of meteorites:* There has been a strong tendency for many years to regard meteorites as furnishing the materials for the earth. They still come in millions of tons every year, contain many of the ingredients of the earth's crust and could furnish the heavier materials that are believed to compose the central iron core and the zones that are believed to lie between the core and the crust and which we are unable to study "in the flesh." The average of meteorites is thought to closely resemble the average of materials in the earth.

*Origin of the earth:* There are many hypotheses but none is entirely satisfactory. Some suit the geologist fine, but astronomers disagree with them. Consider the Nebular or Laplacian hypothesis. What made rings of different volume come off at different times, making the planets different sizes? Are the granites of the Precambrian age the original crust? Or the Planetesimal hypothesis of Chamberlin and Moulton. It works nicely from the standpoint of the geologist with the heaviest material in the centre, but the astronomers raise objections. Gravity is the dominant factor and it allows for the differentiation of the acid and basic rocks, and doesn't require a period of cooling. There are the sun-bolt and gas-tidal hypotheses of Jeans and Jeffreys. Jeffreys returns to the old idea that the earth was initially gaseous. Spitzer says the materials composing the earth could not have been obtained by direct condensation of material torn from the sun. L. H. Adams suggested condensation of material in the earth occurred from the bottom upward.

No matter how the earth originated and the long periods of time that may have preceded formation of the first rocks, geologists and physicists believe the earth has been very much as it is now for two billion years, and that, considered as a whole, the temperature of the surface through the past ages has been very much as it is to-day. Glacial epochs occurred away back in Precambrian time and normal processes of erosion and sedimentation have operated along with volcanic activity, mountain building and other phenomena for two billion years, and we believe these processes will continue for perhaps as much longer unless the astronomers discover some way of putting an end to the earth.

Dr. Helen S. Hogg presented the sixth and final paper in the series on "Major Advances of the Twentieth Century in Astronomy." She dealt with "The Rotation of Our Galaxy." A summary follows:

This century has shown us that our solar system is situated in a vast but finite system of stars which we call our galaxy. The Milky Way represents the fundamental plane of this system and the stars are highly concentrated to it. It probably takes light about 100,000 years to cross the greatest diameter of the system

The sun is situated about 30,000 light-years distant from the centre in Sagittarius. With the exception of the extra-galactic nebulae everything in the sky belongs to our own galaxy. This includes our solar system, the sun, planets, satellites, comets and meteors. Our sun is only one of the thousands of millions of stars which our galaxy contains. Variable stars, binary stars, novae, planetary nebulae, great gaseous nebulae and dark clouds of gas abound in it. The dark gas clouds unfortunately obscure some of the most important regions in the sky and dim the light of the stars in the Milky Way by a factor of about 0.7 mag. for every 1000 parsecs of distance that we go out from the sun.

Sir William Herschel in 1783 showed that our sun was moving toward the constellations of Hercules and Lyra with a speed of about 13 miles a second. Other stars have comparable speeds in various directions. During this century, however, preferential motions of much greater magnitude among the stars were established, notably by Kapteyn in his phenomenon of star streaming, and by Stromberg at Mount Wilson in his asymmetrical motions of high-velocity objects such as cluster-type variables. Lindblad of Sweden originated the theory that our sun is revolving around the centre of our galactic system. As developed by other investigators, including Oort of Holland and Plaskett and Pearce at Victoria, this theory can explain practically all the observed motions of stars, both proper motion and radial velocity, and can be made to account for the conspicuous phenomenon of star streaming. Study of motions of the stars indicates our sun is describing an elliptical orbit around a massive centre in Sagittarius, about 30,000 light-years away. It is moving at a rate of about 250 km./sec. and will go around once in about 200,000,000 years. This time for the sun to travel once around the distant centre is called a *cosmic year*.

Present theories indicate the total mass of our galaxy is about 200,000,000,000 solar masses; approximately half of this is in the central nucleus in Sagittarius, apparently hidden behind the obscuring clouds. The stars nearer the galactic centre move somewhat faster than the sun; those farther away move more slowly (just as planets around the sun). No stars apparently are moving with a speed greater than 300 km./sec. Any stars moving so quickly have long since been hurled out of our system into intergalactic space.

The globular clusters form a rather stationary super-system which is not flattened out like our galaxy, and do not share in the general rotation. The motion of the sun may be derived from them. The rotation of our galaxy may be inferred from analogy with nearby extra-galactic systems in which we can observe actual rotation shifts with the spectroscope. In some of these nebulae, the nucleus apparently rotates as a solid body with its outer edge moving fastest, while the outer parts of the nebula rotate as individual bodies. The stars more distant from the centre move more slowly. Eventually photography in red light will help us to penetrate part of the obscuring matter and will add to our knowledge of the more distant parts of the galaxy.

The chairman announced that the Society had been invited to take part in a special meeting arranged by the University and other bodies in Convocation Hall on April 26 to commemorate the 400th anniversary of the death of Nicholas

Copernicus. . . . The Society also planned its own observance of the Quadricentennial on May 24, it was announced.

Success of the series of outdoor observation meetings during the summer of 1942 had been so marked, the Council had arranged a similar series for the coming summer, the chairman said. An announcement with the dates would be mailed to members in a short time, she added.

*Special Meeting, April 26, 1943.*—The Society met in conjunction with the University of Toronto, Royal Canadian Institute, and Canadian Friends of Poland, at a special session in Convocation Hall, University of Toronto, to commemorate the four hundredth anniversary of the death of the Polish astronomer, Nicholas Copernicus.

The meeting, which commenced at 8.15 p.m., was under chairmanship of Dr. H. J. Cody, President of the University. After the singing of "God Save the King" and the Polish national anthem, addresses were given by His Excellency, Mr. Victor Podoski, Minister of Poland to Canada; Prof. B. Wilkinson, department of history, University of Toronto, and Mr. Otto Holden, President of the Royal Canadian Institute, who represented the scientific and engineering societies of Toronto.

The main address was delivered by Prof. Oscar Halecki, Director of the Polish Institute of Arts and Sciences in America. Speaking on "Copernicus and His Age," Prof. Halecki traced not only highlights of the life of the 16th century philosopher who is now regarded as the father of modern astronomy, but also described economic and political conditions in Poland during Copernicus's time and later.

The speakers were thanked on behalf of the large audience by Dean C. R. Young of the faculty of applied science, University of Toronto, and chairman of the Toronto branch, Canadian Friends of Poland; and by Dr. C. A. Chant, professor-emeritus of astrophysics, University of Toronto, who spoke on behalf of astronomers and of the Society. The meeting closed with the singing of the Polish national hymn.

FREDERIC L. TROYER, *Recorder.*

## AT VICTORIA

*Summer Evenings with the Stars.*—With a programme planned for the benefit of those making their first acquaintance with Astronomy, the twelfth annual Summer Course of the Victoria Centre was well attended by an enthusiastic audience. Keen interest was shown in the lectures, and large numbers turned out to the Centre's observing station to attend the observational meetings. Following is a schedule of the meetings:

*Aug. 2, 1943.*—The Moon, Lft. Comdr. P. H. Hughes
*Aug. 9, 1943.*—Outdoor Observational Meeting
*Aug. 16, 1943.*—Constellations, Dr. R. M. Petrie
*Aug. 23, 1943.*—Outdoor Observational Meeting
*Aug. 30, 1943.*—Solar System, Dr. K. O. Wright.

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## 1890-1943

The Society was incorporated in 1890 under the name of The Astronomical and Physical Society of Toronto, and assumed its present name in 1903.

For many years the Toronto organization existed alone, but now the Society is national in extent, having active Centres in Montreal and Quebec, P.Q.; Ottawa, Toronto, Hamilton and London, Ontario.; Winnipeg, Man.; Edmonton, Alta.; Vancouver and Victoria, B.C. As well as about 800 members of these Canadian Centres, there are over 200 members not attached to any Centre, mostly resident in other nations, while some 300 additional institutions or persons are on the regular mailing list for our publications.

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Membership is open to anyone interested in astronomy. Annual dues, $2.00; life membership, $25.00. Publications are sent free to all members or may be subscribed for separately. Applications for membership or publications may be made to the General Secretary, 198 College St., Toronto.

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